Summary

Reducing building energy consumption while ensuring indoor comfort conditions is becoming everyday more important. Such challenges cannot be approached using traditional solutions, but require a change of paradigm. This transition has already started, as new concepts are arising: *energy flexibility* is gaining importance, demanding improvements in terms of the ability of a building to manage its demand and generation; *responsive building* concepts are replacing the *static* ones, pushing toward building adaptation to changing boundary conditions and requirements.

In this context, *adaptive building façades* represent a promising solution to improve buildings flexibility and responsiveness, providing the building envelope the abilities to change its thermos-optical properties to respond to changing boundary conditions (e.g. weather, occupancy) or requirements (e.g. comfort levels). However, these technologies are rarely implemented in the current building stock.

Control strategies play a central role in the exploitation of adaptive building façades. Despite the widespread use of advanced control strategies in many fields often related to industrial applications, little has been explored for applications involving adaptive façade components.

In this framework, this doctoral dissertation sets out to investigate the opportunities arising from using *advanced control strategies* to operate *adaptive building components*. This endeavour involved different steps. Adaptive building technologies and control strategies were explored through a literature review, with particular focus on components for solar gains modulation and advanced predictive control strategies. Following a pragmatic approach, a Hybrid Model Predictive Control strategy (HMPC) for the operation of an active façade based on electrochromic windows was designed and implemented in two case studies. This

activity involved the development of physical models (*white-box*) and simplified data-driven models (*grey-box*) to accurately describe and predict the thermal dynamics of the systems. Characterization and monitoring of the real case study were carried out to validate the respective physical model and enable the implementation of a real-time control system. A toolchain structure was conceived for the co-simulation and control implementation.

In the first case study, different HMPC strategies were designed to control an electrochromic window with the aim of reducing the heating and cooling energy need. Results based on Key Performance Indicators demonstrated how HMPC strategies outperformed Rule Based Control (RBC) strategies used as baseline and that the possibility to tune HMPC adds flexibility to the controller, which can be regulated according to specific objective functions.

In the second case study, an electrochromic façade was installed in an outdoor test cell (TWINS). The HMPC designed in this case aimed at minimizing the energy need considering the heating, cooling and lighting system. Comparing the HMPC with the baseline strategies, it was demonstrated that the predictive controller was able to better exploit the physical phenomena driving the system evolution, given its prediction abilities and the opportunity to manage contrasting needs

This thesis defines a novel methodology to control active building components using HMPC strategies, able to merge feedback control principles with numerical optimization and to manage both continuous and discrete state variables.

The outcomes of the research activities undertaken in this PhD highlight the importance of control strategies on active building components, showing how an advanced control strategy such as the MPC, on the one hand opens a new set of possibilities (e.g. managing contrasting needs, account for constraints) and on the other hand enhances the performance of these systems.